Get Energised!

Pupil Challenges

2016–17

Foundation SCOTTISHPOWER

National Museums Scotland

Get Energised!

Pupil Challenges

The activities in this pack accompany the Get Energised Challenge Days events at National Museums Scotland. Teachers' Guides with content on renewable energy are available for both primary and secondary teachers.

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Hydro Power Challenge

Team name: ....

Your challenge is to build a working power station.

You will need to:

(i) Build a model hydropower station (a description of how the power station works can be found on page 4).

(ii) Calculate the gravitational potential energy of your power station and identify sources of loss.

(iii) Design and build a water turbine.

(iv) Record the voltage generated by the turbine.

Your team should present your work through a short verbal report. You must include the source of loss, the gravitational potential energy for your model and the voltage recorded. (2 minutes max).

Organising the Team

1. Choose a Project Manager for the team. This person is responsible for ensuring all the tasks are completed on time.
2. Divide the team into 2 sub-groups:
   a. Sub group 1: Building the model hydropower station
   b. Sub group 2: Design and build a water turbine and record the voltage output of your design.

Equipment

Sub-group 1:

1. To build the model station you will need a high and a low reservoir and some water.
2. To calculate the gravitational potential energy of the power station you will need a metre ruler or measuring tape and a calculator.

Sub-group 2:

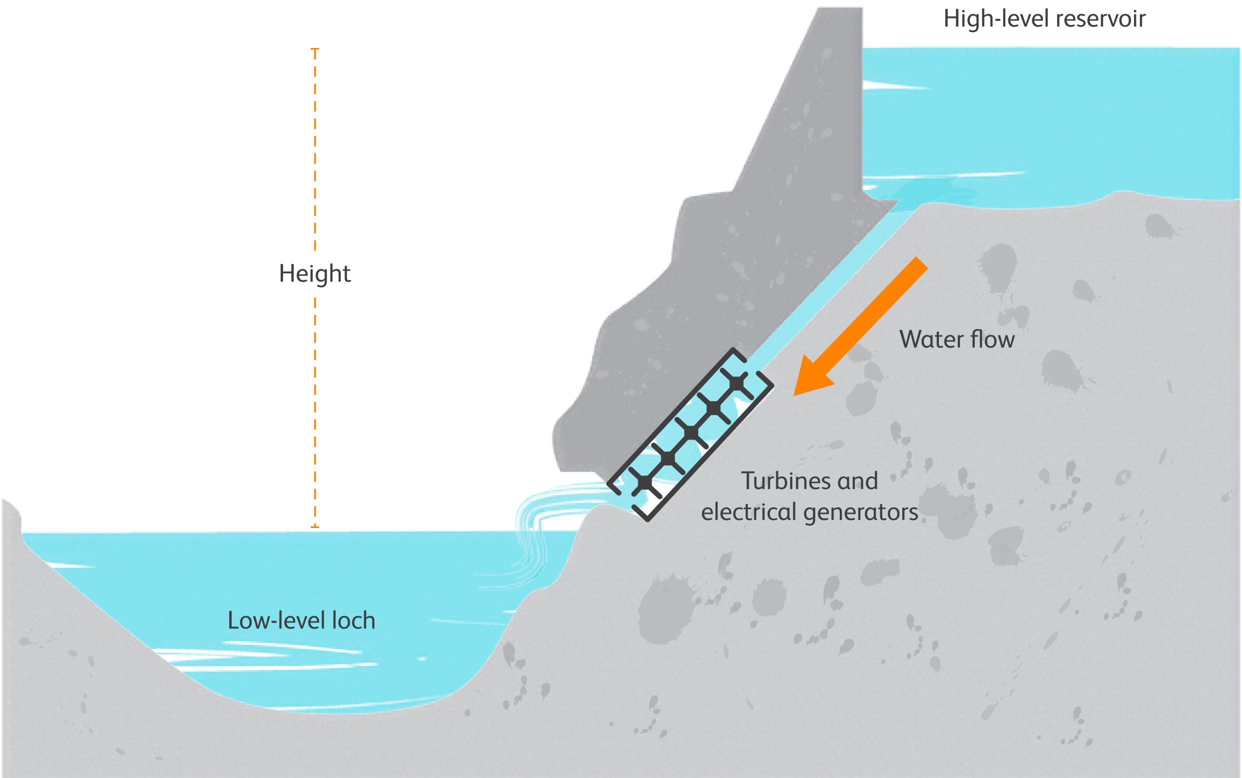
To design and build a water turbine you will need: a plastic bottle, cut into three pieces (top, middle and bottom separated), electrical tape, scissors, connection to electric motor, multi-meter, wires and motor.

Hydro Power Challenge

Team name: ______________________________

There are three main components to the water flow in a hydroelectric power station.

1. A high reservoir.
2. A channel for the flowing water.
3. A low reservoir for the water to flow into.



Useful Information

Height is an important factor when considering the design of a power station. By having water at a height, there is stored energy. It has gravitational potential energy:

$$E_P = mgh$$

Where m is the mass of the water, g is the gravitational field strength and h is the height.

Hydro Power Challenge

Team name: ____________________

Sub-group 1: Building a working Hydro Power station

1. Describe how a hydroelectric power station generates electricity:

____

____

2. Building your model

Show your description from (1) to the member of Museum staff, they will then give you the materials you need. Using the materials provided to you, set out your model station ready for the addition of the turbine from your team mates.

3. Calculating the Gravitational Potential Energy

There are still some unknowns in the equation for gravitational potential energy that you have to find the height of the power station and mass of water as well as the value for g, the acceleration due to gravity.

- To find the height, h: measure the height of your container above the sink or basin.
- To find the mass, m: you can do this if you know the volume of water in the container, as 1 litre = 1 kilogram.
- You should be able to remember the value of g. It is measured in metres per second per second. Find the Gravitational Potential Energy for your model:

E_P=mgh

m =	
g =	
h =	
E_P=	

____

____

4. Identifying Losses

The process of generating electricity is very efficient. When the turbines are running, 80-90% of the energy from the moving water becomes electricity. What is the 10-20% lost as?

____

____

Now join your teammates to finalise the model power station and record a voltage.
Remember to leave enough time to prepare your presentation.

National Museums Scotland

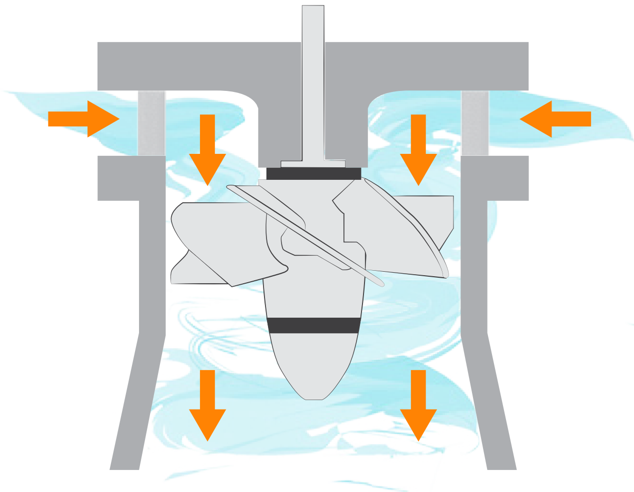
Hydro Power Challenge

Team name: --

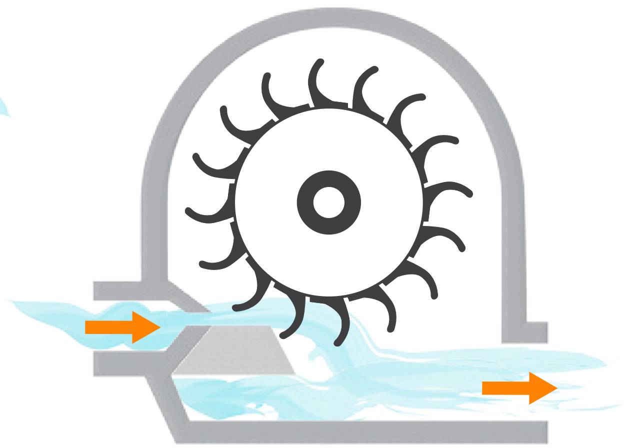
Sub-group 2: Design and Build a Turbine

The turbine you build will go into the model power station your team mates are building. There are two types of turbines used in hydroelectric power stations: reaction and impulse.

- A reaction turbine is fully surrounded by water.
- An impulse turbine uses a jet to turn the blades.



Reaction turbine



Impulse turbine

Your challenge is to build an **impulse** turbine. Kinetic energy from the water will become the mechanical energy of your turbine. The turbine then drives the generator to produce electricity.

1. Start by sketching your design. Show your sketch to the member of Museum staff who will then give you your materials.
2. Build and test. Using the materials supplied, design and construct blades that will turn efficiently when the water stream hits.

Remember to test your design and make changes if necessary. Testing is an important part of the design process. Talk to your team mates in Sub-group 1 about sources of loss to see if this influences your design.

3. Record the voltage produced

Practice supplying the turbine with water. Once you are happy that it is turning smoothly, connect the turbine to the electric generator. Supply water to the turbine and measure the voltage and current produced by your hydroelectric power station.

You should record the maximum voltage shown on the multi-meter when your turbine is running in the water. If you have time you can improve your design and record another voltage.

Voltage = | |
|---|

Remember to leave enough time to prepare you presentation.

Solar Power Challenge

Team name: ....

National Museums Scotland would like to install solar panels on the museum roof. There are three possible positions for the solar panels. Your challenge is to choose which position to use and construct a model of the array of solar panels.

You will need to:

(i) Investigate how a solar panel works.

(ii) Understand the factors that affect the output of a solar panel.

(iii) Construct a model of the solar array.

Organising the Team

1. Choose a Project Manager for the team. This person is responsible for ensuring all the tasks are completed on time.
2. Divide the team into 2 sub-groups
    a. Sub-group 1: Research unit to investigate how a solar panel works.
    b. Sub-group 2: Engineering unit responsible for choosing the position of the solar array on the roof and constructing a model.

Equipment

Sub-group 1:

- Solar panel, multi-meter, wires, ruler or measuring tape, protractor, lamp, 100 Ω resistor, string, calculator, piece of card.

Sub-group 2:

- Building materials, such as LEGO.

Solar Power Challenge

Team name: ....

Sub-group 1: Research Unit

Your sub-group's task is to understand the factors that affect the operation of a solar panel. This will allow you to advise your team mates on construction of a model.

Part 1. Solar panel output

Every solar panel has a rated power output established under set test conditions (when the Sun is directly above the panel on a clear day). This allows an estimate to be made of the electricity output before the panel is installed.

You can find the power output of this solar panel.

1. Hold the solar panel 20cm away from the light source with the panel directly facing it.
2. Turn the light on and record the voltage shown on the multi-meter.

   Voltage, V = [ ]

3. A 100 Ohm resistor is being used in the circuit. You can use the knowledge of the resistance to calculate the current, I:

   $V = IR \rightarrow I = \frac{V}{R}$ Current, I = [ ]

4. You now have enough information to calculate the Power, P of the panel and complete the solar panel technical information table below.

   $P = I \times V$ Power, P = [ ]

Solar panel technical information:

Power output	
Width	
Height	
Technology	Polycrystalline

When installed will the output of the solar panel be constant throughout the day? Explain your answer.

....

....

....

Will the output of the solar panel be constant across the year? Explain your answer.

....

....

....

Solar Power Challenge

Team name: ....

Part 2. Solar panel positions

There are many factors that influence the output of a solar panel. This includes shadows created by a tree or a chimney. Shadows can dramatically reduce the amount of electricity generated as the sunlight is prevented from reaching the panel.

What other factors will reduce the total amount of electricity produced by the solar array?

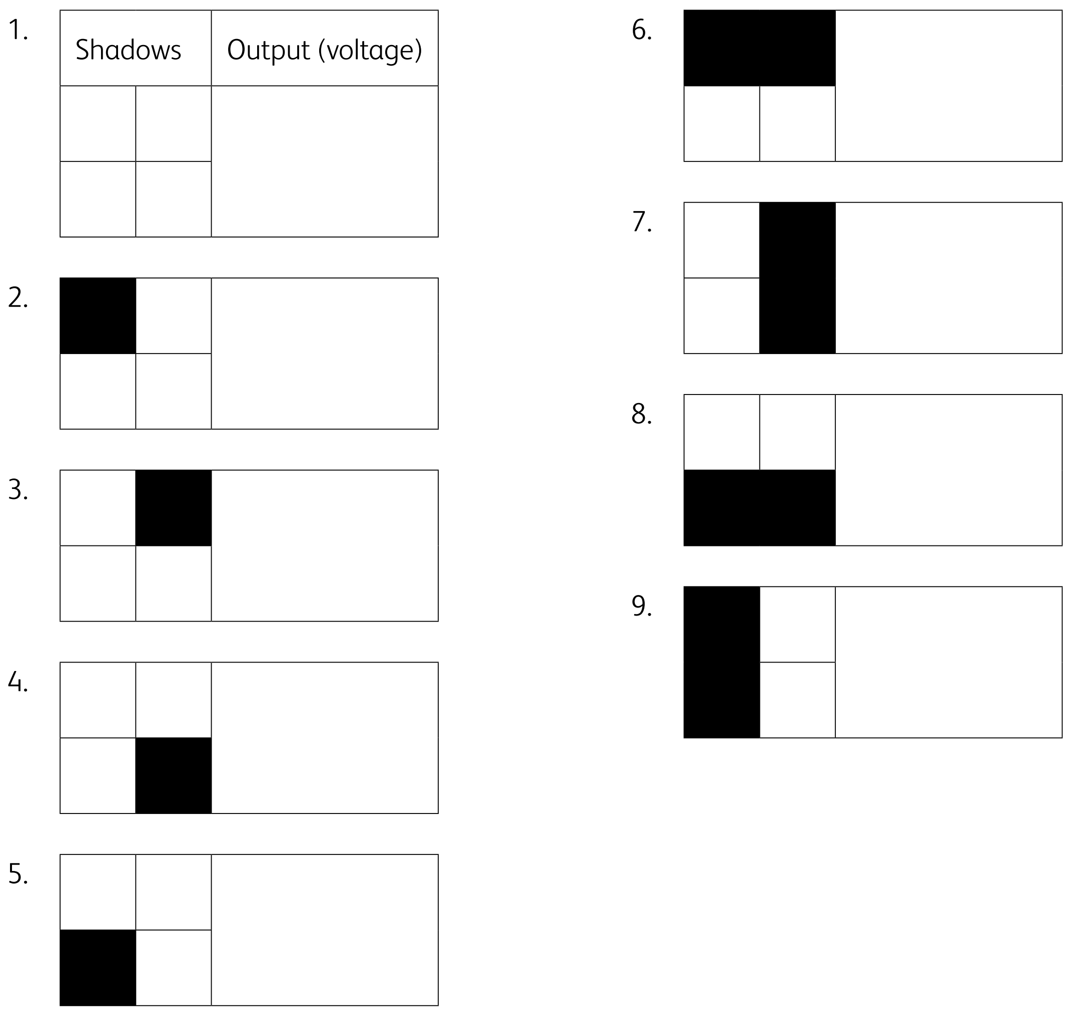
....

....

....

By investigating the effect shadows can have on the output of the solar panel you can advise your team mates on how to arrange the panels in your model.

- In the diagrams below, the solar panel has been split into quarters. Using a piece of card cover up the square shown and write down the voltage.
- Diagram number 1 is to record when the panel is not covered.
- As in your previous measurement hold the solar panel 20cm away from the light source with the panel directly facing it. The silver strip on the panel should run top to bottom, not left to right.



National Museums Scotland

Solar Power Challenge

Team name: ________________

Describe the effect shadows have on the output of the solar panel.

____

____

____

You should communicate your findings to your team mates and help to finalise the model.

Part 3. Presentation of results

Alongside your team mates in sub-group 2 you should present your model and include any factors you thought may affect the output of the solar array.

Solar Power Challenge

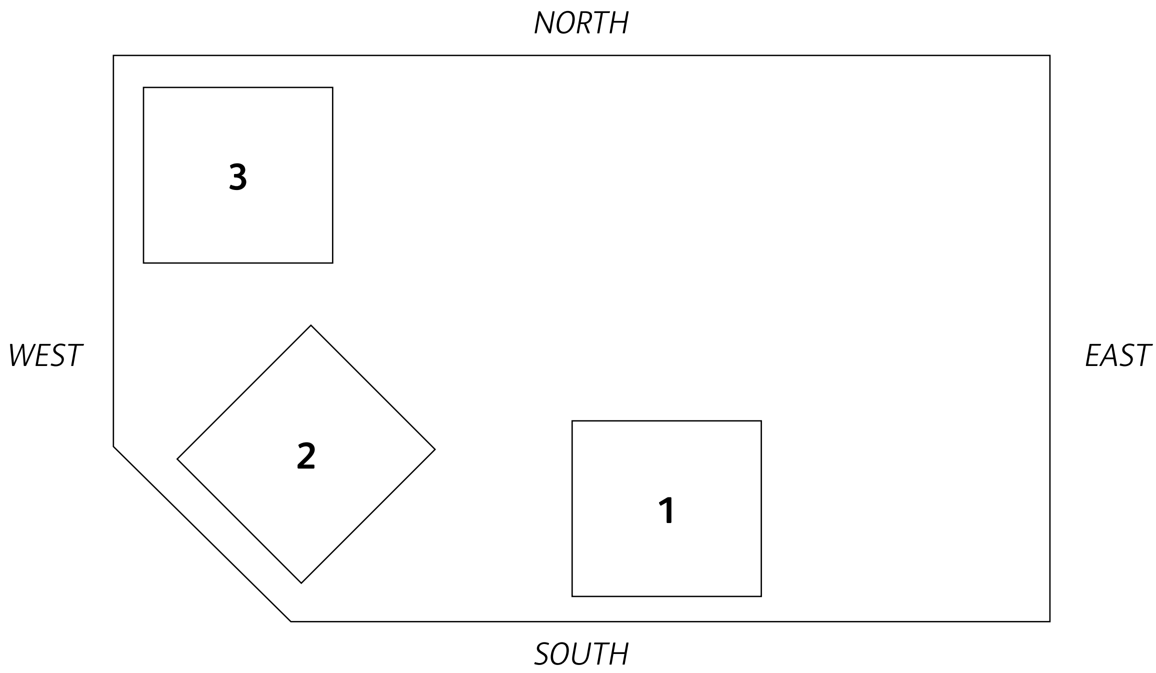
Team name: --

Sub-group 2: Engineering Unit

Part 1. Choosing a site

A solar array will be placed on the roof of the National Museum of Scotland at Chambers Street. Your sub-group needs to decide what position to place the array in and then build a model.

There are three potential sites to consider and are shown in the diagram below:



The same area (7m by 7m) is available at all three positions, however there are some differences:

- Position 1 includes a 2m high and 1m wide wall around the perimeter.
- Position 2 has a 2m high, 1 m wide and 4 m long raised bed filled with shrubs and flowers sitting on the outside wall.
- A 3.5m high and 0.5m wide chimney sits in the middle of position 3.

In your sub-group discuss the different options and their advantages and disadvantages. One of the main aspects to consider is the shadow cast by objects as the Sun's position in the sky changes through the day. Discuss your ideas with your other team mates in sub-group 1 before making your final decision.

Chosen position = [ ]

Please explain your choice:

Solar Power Challenge

Team name: ....

Part 2. Building a model

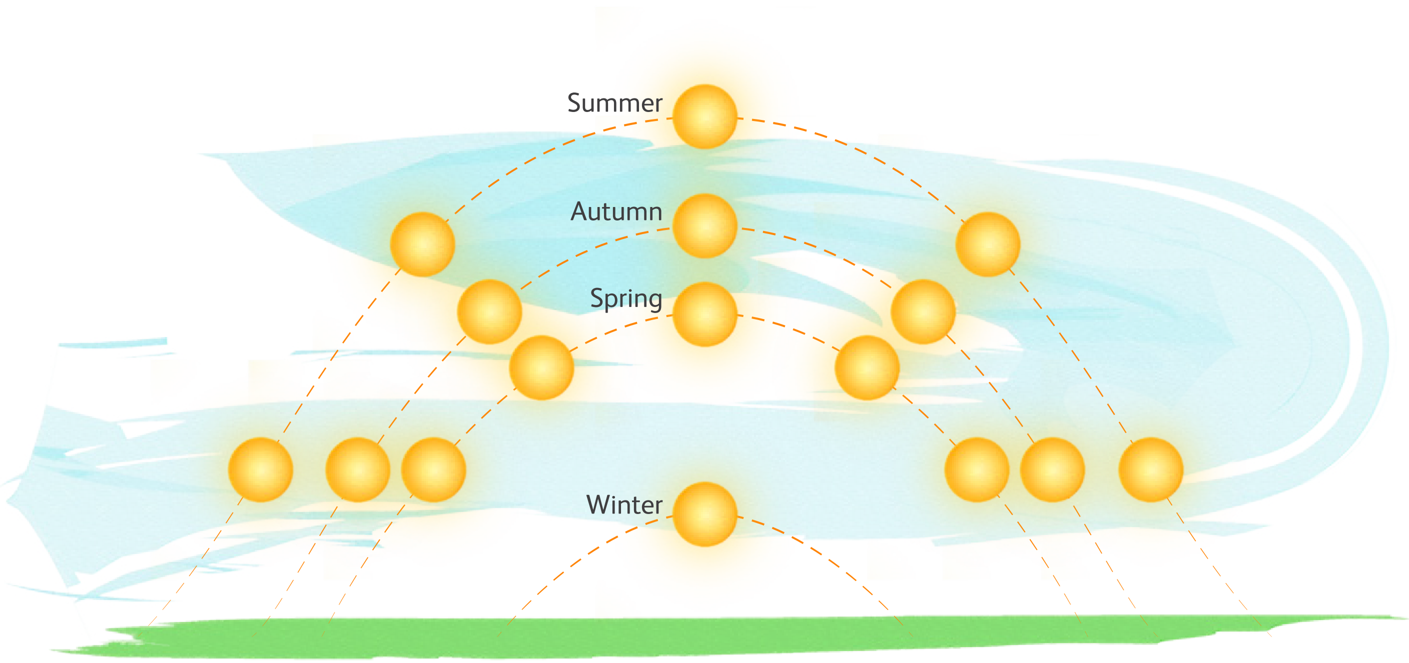
Now that you have identified the position of your array you need to construct your model. Depending on the position chosen you must include the wall/flower bed/chimney as part of your model.

Solar array specification:

Area available	7m by 7m
Angle of panels*	45 degrees
Min/max number of panels	N/A – try to fit in as many as possible

**Panels are angled towards the Sun to gather as much light as possible. The Sun moves during the day and is a different height in the sky across the seasons so an angle is chosen as a "best-fit".*

- If shadows fall on your panels the total output will be greatly reduced, your team mates are investigating this and can advise you on the affect they have.
- Once built, use a lamp to represent the Sun (you can borrow this from your team mates) go from sunrise to sunset over your model to get an idea of where the shadows lie. The height of the Sun in the sky is different across the seasons, as seen in the diagram below.



Solar Power Challenge

Team name: ________________

You have been given scale models of the solar panels that will be installed to use in your model. Using the building materials provided you can construct your array. The details of the actual panels to be installed can be found below.

Solar panel technical information:

Power output	300 W
Width	1.5 m
Height	1.5 m
Technology	Polycrystalline

Number of solar panels = ☐ Area of solar panels = ☐

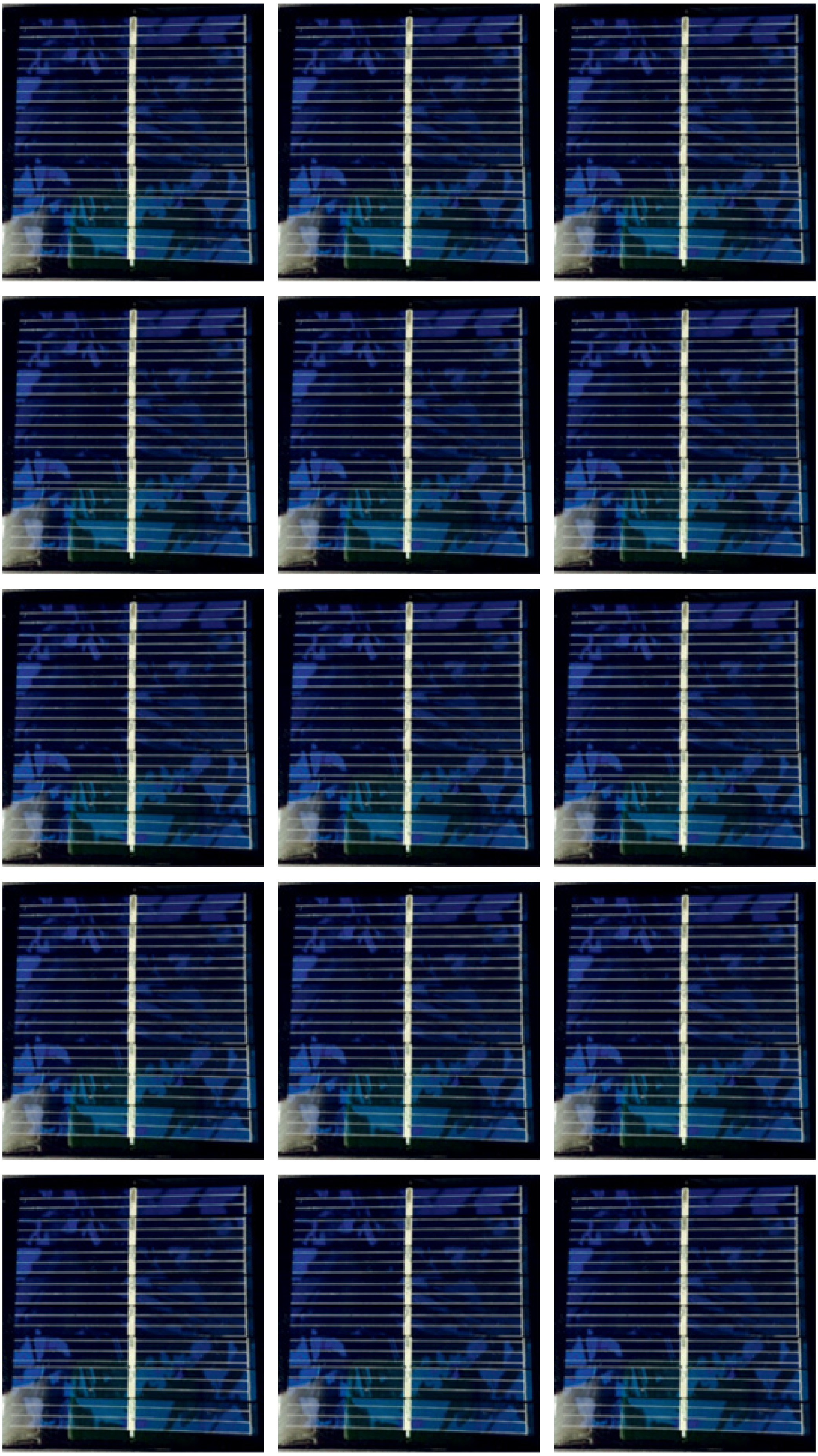
Part 3. Presentation of results

Alongside your team mates in Sub-Group 1 you should summarise why you decided on your chosen position and describe the reasoning behind the layout of your solar panel array.

Solar Power Challenge

Team name: ....

Solar panels for model building



Wind Power Challenge

Team name: ______________________

Your challenge is to design a wind turbine suitable for use in an offshore wind farm.
Wind turbines found at an off-shore wind farm will experience higher average wind speeds than those found on land. This means that the turbine blades must be built to last in these higher wind speeds. You need to investigate

(i) What number of blades gives the highest electricity output.

(ii) What angle of blades gives the highest electricity output.

(iii) Changing the shape of the blades to increase output further.

Your team should present your model turbine, describing the processes of designing and testing that you went through to reach the final result (2 minutes max).

Organising the team

1. Choose a Project Manager for the team. This person is responsible for ensuring all the tasks are completed on time.
2. Divide the team into 2 sub-groups::

a. Sub-group 1: investigate number and angle of blades

b. Sub-group 2: investigate shape of blades

Equipment

Wind turbine kit, protractor, materials for shaping turbine blades.

Wind Power Challenge

Team name: ---

Sub-group 1: Investigating number and angle of blades

- There are two testing stations available that are shared between all of the teams completing the challenge, so you need to manage your time carefully.
- Your sub-group needs to find the combination of number of blades and blade angles that gives you the highest electricity output. In order to do this you need to come up with a plan for testing. This could mean testing all of the combinations you can think of, or choosing a sample of numbers of blades and angles to see what gives you the best output. When testing the fan should be on the highest setting to replicate the fastest wind speed.
- Your whole group should discuss and write up a testing plan on a separate piece of paper. This should include a table that will be used to gather your results. Show this to the Challenge Leader and they will allow you access to the testing station to get started.
- Your teammates in sub-group 2 will be working on changes to the blade design. You need to communicate with them to let them know the number and angle that give the most electricity as this will be likely to affect their design.
- Once testing the number of blades and angles has finished join sub-group 2 to finalise the design.
- At least one measurement of the output of the final design of the wind turbine needs to be recorded. The number and angle of blades used in your final turbine design should be based on the work by sub-group 1 and the straight blades should be replaced by the design made by sub-group 2. As a team you will present your design and the voltage generated.

Wind Power Challenge

Team name: --

Sub-group 2: investigating blade design

- Before splitting from sub-group 1 you need to work with them to develop a testing plan for the blades. Once they start testing you can begin work on blade design.
- The blades that are provided in the wind turbine kit are straight and thin pieces of plastic. Think about the shape of the blades you have seen on wind turbines, describe the shape below.

- Your sub-group has been provided with a set of materials to change the shape of the blades. Based on these make a sketch below of how you would like to change the blades.
- Show your design to the Challenge Leader and they will provide the rest of the materials you need to get started.
- You can now begin to make changes to the blades. There are two testing stations available for you to use. It is important that you test your design to see what effects your changes have on the output. When testing the fan should be on the highest setting to replicate the fastest wind speed.
- Throughout the design process you need to communicate with sub-group 1 as they will be providing you with information on how many blades and at what angle they will be arranged in the final set up. Remember that the number and angle will affect your design. Sub-group 1 will join you to finish the design of the blades.
- At least one measurement of the output of the final design of the wind turbine needs to be recorded. The number and angle of blades used in your final turbine design should be based on the work by sub-group 1 and the straight blades should be replaced by the design made by sub-group 2. As a team you will present your design and the voltage generated.

Marine Power Challenge

Team name: ....

You have been given £5,000,000 to invest in the development of a type of marine power technology. Your challenge is to choose between tidal and wave power technologies. To make a decision you will need to take measurements and test each marine model to learn more about how it works.

You will need to:

(i) Research wave characteristics, such as frequency, amplitude and wavelength.

(ii) Investigate how the two kinds of technology work and find out more about the company developing it.

Your team should present your decision in a short verbal report (2 minutes max).

Organising the Team

1. Choose a Project Manager for the team
2. Divide the team into 2 sub-groups and choose a group leader for each group. Each sub-group is responsible for investigating a different type of marine power technology in part 2.

Equipment

Part 1: A wave tank with wave generator, ruler, calculator.

Part 2:

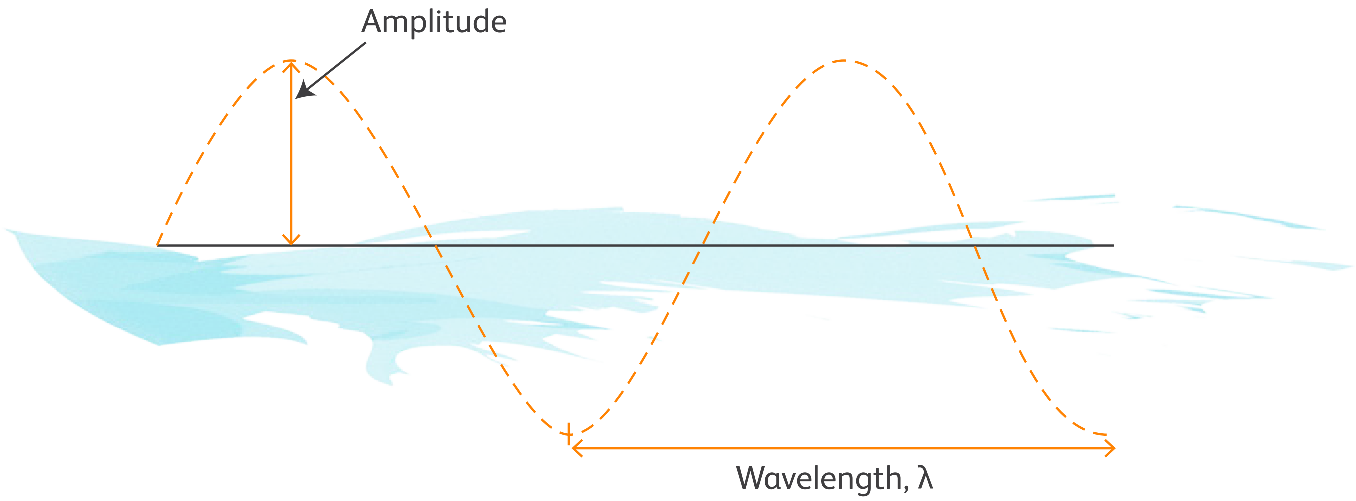
- Sub-group 1: A wave tank with wave generator, a model of a wave power technology.
- Sub-group 2: A water tank, a model of a tidal power technology.

Marine Power Challenge

Team name: --

Part 1. Researching wave characteristics

- Amplitude: this is the height of the wave as measured from its calm or undisturbed state
- Wavelength: this is the distance between two points, each on the same point on two different waves
- Frequency: this is the number of waves that pass a certain point in a second, measured in Hertz, Hz.



The waves used for generating electricity have been built up across vast distances. However, the speed of a wave is frequency times wavelength.

Using the wave tank, find the frequency of the waves in the tank. Set the dial first at 12 o'clock and then 5 o'clock. You can find the frequency by counting the number of waves that pass a point in a set time, then divide by the number of seconds.

Dial position	Frequency (Hz)
12 o'clock	
5 o'clock	

Marine Power Challenge

Team name: ....

Part 2. Investigating marine power technologies

Background Research

Split into your 2 sub-groups. Each group should investigate one of the technologies and associated company. You will find information about the companies and technologies in the Company Information sheets. Find out the following and record your findings in the Company 1 and 2 answer sheets:

1. **Market Potential**

   The number of potential locations on the Scottish coast which meet the technical requirements for each technology are unknown. Using the chart of the Scottish coast and the location information sheet identify the number of potential sites.

   a. Company 1: Refer to the technical specification for this company in the Company 1 information sheet. Use this information to find the potential sites.

   b. Company 2: This company has not supplied technical information. Based on where their technology is either already being used (position 4 on the chart) or where a site is under construction (position 13 on the chart), make an estimate of the technical requirements for the technology. Identify any other potential sites.

2. **Profit**

   a. Using the financial information in the company information sheets, calculate the investor share of the profit after 3 years.

   b. Will they recover their £5,000,000 investment after 3 years?

3. **National Grid**

   Moving electricity to where it is needed by homes and businesses is very important. The National Grid is used to move electricity around the country. It can be expensive to install new links to the grid. Using the map of National Grid connections, is there a connection available at the potential locations you have identified?

Testing

Both companies have fully tested a scale model prototype, however they have not shared the results of the tests. You can test each model in a tank and observe the behaviour of the model.

Here are some example questions to investigate:

- How does the model behave in small waves or slow-moving tide?
- How does the model behave in large waves or fast-moving tide?

Summarise the advantages and disadvantages of each technology.

 Team name:

Part 3. Investment Decision

Each sub-group should now share the information they have found with the rest of the team.

Based on what you have learned, which marine power technology do you want to invest in and why?

Marine Power Challenge

Team name: ______________________________

Sub-group 1
Company 1 Answer Sheet

Background Research

Find out the following and record your findings on Company 1 on this sheet:

1. **Market Potential**

   Using the chart of the Scottish coast and the location information sheet, identify the number of potential sites.

a. Company 1: Refer to the technical specification for this company in the Company 1 information sheet. Use this information to find the potential sites.

   Number of sites = ☐

   Location numbers of sites: ☐

2. **Profit**

a. Using the financial information in the company information sheets, calculate the investor share of the profit after 3 years.

   Investor share = ☐

b. Will they recover their £5,000,000 investment after 3 years? Yes ☐ No ☐

3. **National Grid**

   Using the map of National Grid connections, is there a connection available at the potential locations you have identified? List the location number of the sites below.

   Yes, connection is available at these sites: ☐

   No, connection is not available at these sites: ☐

Testing

- How does the model behave in slow-moving tides?
- How does the model behave in fast-moving tides?

Summarise the advantages and disadvantages of the technology using the reverse of this answer sheet.

Marine Power Challenge

Team name: --

Sub-group 1
Company 1 Information Sheet

Tidal turbine

The turbine sits under the surface of the sea and is fixed to the sea bed. As the tide moves past, the blades turn and this movement generates electricity.

		Technical requirements	
Technology name	**Phase**	**Average tidal power**	**Sea depth**
Tidal turbine (TT)	Version 2 (v1 prototype tested at the European Marine Energy Centre, Orkney)	1 kW/m^2	5-10 m

Benefits

- This technology harnesses the renewable power of the tides to generate clean energy.
- It is an efficient process with 45% of the total energy being used to generate electricity.
- It is thought that one full working turbine will have a capacity of 250kW. There can be multiple turbines at each site.

Financial Forecast

This is an established company with £5 million investment already secured.

If your investors put in £5 million, then they will own 22% of the business and be entitled to 22% of any profit made. The projected accounts for the next three years are as follows:

Year	Turnover	Profit or Loss	Activity
1	£5,000,000	-£100,000	Build and test version 2
2	£20,000,000	£11,000,000	Open first power station and begin electricity generation
3	£30,000,000	£14,000,000	Open two further power stations

Potential Risks

The following items have been identified as potential barriers to success. An estimate has been made of how likely these are to occur. These items could affect the profitability of the business.

Possible negative impact to local fishing industry	30%
Efficiency less than expected due to unpredictable weather conditions *	40%
Costs to connect to National Grid higher than expected	25%

* *high wave heights can affect the operation of the turbine as they interfere with the tide*

Marine Power Challenge

Team name: ________________________

Sub-group 2
Company 2 Answer Sheet

Background Research

Find out the following and record your findings on Company 2 on this sheet:

1. Market Potential

Using the chart of the Scottish coast and the location information sheet, identify the number of potential sites.

a. Company 2: This company has not supplied any technical information. Based on where their technology is either already being used (position 4 on the chart) or where a site is under construction (position 13 on the chart), make an estimate of the technical requirements for the technology. Identify any other potential sites.

Number of sites = [ ]

Location number of sites: [ ]

2. Profit

a. Using the financial information in the company information sheets, calculate the investor share of the profit after 3 years.

Investor share = [ ]

b. Will they recover their £5,000,000 investment after 3 years? Yes [ ] No [ ]

3. National Grid

Using the map of National Grid connections, is there a connection available at the potential locations you have identified? List the location number of the sites below.

Yes, connection is available at these sites: [ ]

No, connection is not available at these sites: [ ]

Testing

- How does the model behave in small waves?
- How does the model behave in large waves?

Summarise the advantages and disadvantages of the technology using the reverse of this answer sheet.

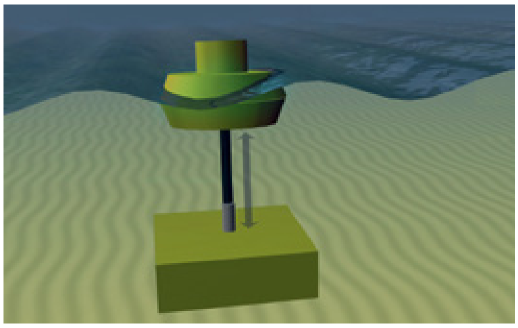
Marine Power Challenge

Team name: ______________________________

Sub-group 2
Company 2 Information Sheet

Wave buoy

The buoy is anchored to the sea bed but sits on top of the sea surface. The buoy moves up and down with the waves. This movement generates electricity.



		Technical requirements	
Technology name	**Phase**	**Significant wave height (m)**	**Sea depth**
Wave surfer (WB)	Final version	Not supplied	Not supplied

Benefits

- This technology harnesses the renewable power of the waves to generate clean energy.
- It is an efficient process with 25% of the wave energy being used to generate electricity.
- There is one fully operational site (position 4) with one more under construction (position 13).

Financial Forecast

This is an established company with a site already established and generating electricity.

If your investors put in £5 million, then they will own 10% of the business and will be entitled to 10% of any profit made. The projected accounts for the next three years are as follows:

Year	Turnover	Profit or Loss	Activity
1	£25,000,000	£5,000,000	Operate one power station
2	£40,000,000	£20,000,000	Begin construction on 2nd power station
3	£60,000,000	£40,000,000	Two power stations operational

Potential Risks

The following items have been identified as potential barriers to success. An estimate has been made of how likely these are to occur. These items could affect the profitability of the business.

Possible negative impact to local fishing industry	30%
Efficiency less than expected due to unpredictable weather conditions	40%
Costs to connect to National Grid higher than expected	25%

Marine Power Challenge

Team name: ....

Potential sites for marine power

Site	Depth (m)	**Significant wave height (m)** Average height of the highest third of the waves	Average tidal power (kW/m^2)
1	40-50	1.26 – 1.5	3.01-4.00
2	5-10	1.26 – 1.5	1.01-1.50
3	40-50	1.76 – 2.00	3.01-4.00
4	5-10	1.26 – 1.5	3.01-4.00
5	5-10	1.26 – 1.5	0.01-0.05
6	30-40	2.26 – 2.5	0.01-0.05
7	5-10	2.26 – 2.5	0.01-0.05
8	5-10	1.26 – 1.5	0.01-0.05
9	5-10	1.26 – 1.5	0.51-1.00
10	30-40	1.51 – 1.75	0.51-1.00
11	5-10	1.01 – 1.25	1.01-1.50
12	5-10	1.01 – 1.25	3.01-4.00
13	5-10	1.26 – 1.5	4.01-5.00
14	30-40	1.26 – 1.5	0.01-0.05
15	30-40	1.76 – 2.00	0.01-0.05
16	20-30	2.01 – 2.25	0.01-0.05
17	30-40	2.01 – 2.25	0.01-0.05
18	5-10	2.01 – 2.25	1.01-1.50
19	30-40	2.26 – 2.5	0.01-0.05
20	20-30	2.26 – 2.5	3.01-4.00
21	5-10	2.26 – 2.5	0.01-0.05